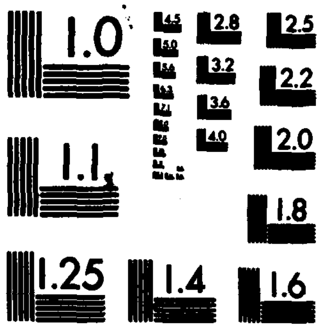
AD-A128 944 COMPARISON OF DOWN-AND FEATHERS AND SYNTHETIC INSULANTS 1/1
FOR USE IN SLEEPING BAGS(U) DEFENCE RESEARCH
ESTABLISHMENT OTTAWA (ONTARIO) R M CROW ET AL. JUL 82
UNCLASSIFIED DREO-866 F/G 6/17 NL

END
DATE
FILMED
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

RESEARCH AND DEVELOPMENT BRANCH
DEPARTMENT OF NATIONAL DEFENCE
CANADA

DEFENCE RESEARCH ESTABLISHMENT OTTAWA

DREO REPORT NO. 866

COMPARISON OF DOWN-AND-FEATHERS AND SYNTHETIC INSULANTS FOR USE IN SLEEPING BAGS

by

R.M. Crow, R.W. Nolan, S.W. Cattroll and M.M. Dewar

PROJECT NO. 250

JULY 1982
OTTAWA

CAUTION

This information is furnished with the express understanding that proprietary and patent rights will be protected.

RESEARCH AND DEVELOPMENT BRANCH

DEPARTMENT OF NATIONAL DEFENCE
CANADA

DEFENCE RESEARCH ESTABLISHMENT OTTAWA

DREO REPORT NO. 866

COMPARISON OF DOWN-AND-FEATHERS AND SYNTHETIC INSULANTS FOR USE IN SLEEPING BAGS

by

R.M. Crow, R.W. Nolan, S.W. Cattroll and M.M. Dewar

Environmental Protection Section
Protective Sciences Division

JULY 1982
OTTAWA

ABSTRACT

A study was carried out to evaluate and compare physically and physiologically three types of synthetic insulating materials and the in-service Canadian Forces down-and-feathers sleeping bag with the ultimate aim of replacing the latter. The insulating materials evaluated were Thinsulate, Polarguard and Hollofil. Polarguard was found to be the optimum substitute for the down-and-feathers.

RÉSUMÉ

Une étude a été réalisée afin d'évaluer et de comparer les propriétés physiques et physiologiques de trois genres d'isolants synthétiques ainsi que les sacs de couchage duvet et plumes dont se servent les Forces canadiennes, en vue du remplacement éventuel de ces derniers. Les isolants soumis à l'évaluation sont le Thinsulate, le Polyguard et le Hollofil. Il s'est révélé que le Polyguard serait le meilleur isolant à substituer au mélange de duvet et de plumes.

INTRODUCTION

This report presents the results of a study carried out to evaluate and compare physically and physiologically three types of synthetic insulating materials and the in-service Canadian Forces down-and-feathers sleeping bag with the ultimate aim of replacing the down-and-feathers. The insulating materials evaluated were Thinsulate (3M Company Limited), Polarguard (Celanese Canada Limited) and Hollofil Dacron II (DuPont of Canada Limited).

Part 1 presents the physical evaluations, Part 2 the effect of laundering on these insulants, and Part 3, the physiological evaluations.

Since this study was started, further work has been done to explain the heat transfer mechanisms in these synthetic battings (1), and to evaluate the optimum insulant for sleeping bags (2).

PART 1 - PHYSICAL PROPERTIES OF INSULATING MATERIALS

MATERIALS

The pertinent physical properties of three weights of Thinsulate Insulation Type "M" (M530, M400 and M200) and one weight of Thinsulate Insulation Type "CS" (CS150), were measured. The Type "M" is a high density batting made from 100% polyolefin microfibre, the Type "CS", a lower density batting, made of polyester staple-fibre and polyolefin microfibre. Five weights of Polarguard (a continuous-filament polyester batting), three weights of Hollofil, (a staple polyester batting) and specimens cut from a new off-the-shelf Canadian Forces sleeping bag containing down-and-feathers completed the series of insulants evaluated.

TEST PROCEDURES

The physical properties which were measured were those directly related to sleeping systems, namely, mass, compressibility and recovery, thickness and thermal resistance.

Except for the mass measurements of the synthetic battings which were carried out in accordance with Can 2-4.2-M77, Method 5A, all tests were done on the specimens used in the measurement of thermal resistance. These specimens were 33 cm diameter circles, cut at random from each batting. To obtain specimens from the down-and-feathers sleeping bag, circles were first stitched around their circumference and then cut from the bag. The reported mass of the latter specimens is for the down-and-feathers component only, i.e., the estimated mass of the shell fabric (which encased the down-and-feathers and acted as a baffle within the specimen) was subtracted from the total mass of each specimen.

The compressibility and recovery measurements, and the thickness measurements were made using a C&R Tester, Model 55. The method for making the compression and recovery measurements was based on ASTM F36-66, Standard Method for Compressibility and Recovery of Gasket Materials. After a pre-load of 0.86 kPa had been applied to the specimen for 15 s, the thickness, P, was recorded. A major load of 7.76 kPa was then applied for 60 s, and the thickness, M, measured. The major load was removed and thickness of the specimen, R, was measured after a further 60 s. The percent compression is given by

$$100 \times (P - M)/P$$

and the percent recovery by

$$100 \times (R - M)/(P - M)$$

The thicknesses of the insulants were measured at the minimum and maximum pressures available with the C&R Tester, 0.16 kPa with a 64.5 cm^2 pressure foot, and 7.76 kPa with a 6.45 cm^2 pressure foot respectively. The two extremes were selected to approximate the thickness of the top and bottom of a sleeping bag with a person sleeping in it. The rest of the procedure for measuring thickness was done in accordance with Method 37, CAN 2-4.2-77, Method of Test for Fabric Thickness.

The thermal resistance measurements were made using the basic two-plate method, given by "Determination of Thermal Resistance of Textiles",

BS 4745:1971, British Standard Handbook 11:1974 4/163. The thermal resistance was measured at the thicknesses corresponding to the two pressures, 0.16 and 7.76 kPa, (i.e. the distance between the upper and lower plates were set to correspond to the mean thickness values measured at each of the two pressures for the batting specimens). Since the down-and-feathers showed considerable variability in thickness from specimen to specimen, the thermal resistance of each specimen was tested at its own mean thickness. The thermal resistance reported is the mean of the three individual thermal resistances.

RESULTS

The results of the physical tests of the insulants are given in Table I. The compression and recovery of the down-and-feathers, the Polarguard and the Hollofil are approximately the same. The dense Thinsulate Type "M" compresses less and recovers more than the other insulating materials. The Thinsulate Type "CS" has an intermediate compressibility and a higher recovery than the other insulants.

As a general rule, the heavier the insulant, the thicker it is, as measured at either 0.16 or 7.76 kPa. Further, the thicker the insulant the more air trapped in it and thus the greater the thermal resistance, with the exception of the Thinsulates. The reason for this is discussed elsewhere (1).

To compare the insulating materials, the thermal resistance per unit mass and per unit thickness is given in Table II. At 0.16 kPa pressure, the down-and-feathers, the Polarguard series and the Hollofil series have about the same thermal resistance per unit mass. The corresponding value for Thinsulate Type "M" is lower by about two thirds and that for Thinsulate Type "CS" is lower by about one half. At the higher 7.76 kPa pressure, the thermal resistance per unit mass is much the same for all the insulants, with the down-and-feathers, Thinsulate Type "M" and Hollofil having slightly less thermal resistance per unit mass than Thinsulate Type "CS" and Polarguard. The thermal resistance per unit thickness at 0.16 kPa is the same for the down-and-feathers and the two types of Thinsulate, and is slightly less for Polarguard and Hollofil. At the higher pressure, the thermal resistance per unit thickness is in the same range for all of the types of insulation tested.

CONCLUSIONS

1. The Thinsulate Type "M" series is the least compressible of the insulating materials tested.

2. At the lower pressure (0.16 kPa), the thermal resistance per unit mass of the down-and-feathers, Polarguard and Hollofil is about three times that of Thinsulate Type "M" and about two times that of Thinsulate Type "CS".

TABLE I

Results of Physical Tests of Insulating Materials

		Down-and-Feathers	Thinsulate				Polarguard					Hollofil		
			M530	M400	M200	CS150	1	2	3	4	5	1	2	3
Mass (g/m^2)	$\bar{x}$	345	545	405	200	175	175	220	255	270	295	185	260	350
	σ	*	16	8	13	12	5	38	23	14	13	23	66	79
	N	3	5	5	5	5	5	5	5	5	5	5	5	5
Compressibility (%)	$\bar{x}$	80	32	34	30	55	82	85	82	82	81	77	81	82
	σ	2	4	3	3	3	3	1	2	2	2	2	1	1
	n	15	5	5	5	5	15	15	15	15	15	15	15	15
Recovery (%)	$\bar{x}$	39	49	55	57	60	47	33	45	44	41	56	44	44
	σ	4	3	4	4	8	5	4	3	3	5	6	3	3
	n	15	5	5	5	5	15	15	15	15	15	15	15	15
Measured at 0.16 kPa														
Thickness (mm)	$\bar{x}$	20.6	8.5	7.7	3.5	5.2	12.4	20.2	24.2	26.3	25.0	12.2	22.0	27.4
	σ	2.0	0.9	0.8	0.2	0.5	1.2	1.4	2.3	3.8	2.3	2.1	3.5	5.2
	n	12	5	5	5	5	15	15	15	15	15	15	15	15
Thermal Resistance (m^2K/W)	$\bar{x}$	0.59	0.27	0.25	0.12	0.16	0.27	0.40	0.46	0.48	0.49	0.30	0.49	0.60
	σ	0.06	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.02	0.04	0.03
	N	3	3	3	3	3	3	3	3	3	3	3	3	3
Measured at 7.76 kPa														
Thickness (mm)	$\bar{x}$	3.4	5.2	4.2	2.0	1.5	1.1	2.2	3.4	3.8	3.7	1.1	2.1	2.6
	σ	0.9	0.5	0.4	0.2	0.3	0.1	0.3	0.6	0.6	0.4	0.3	0.4	0.6
	n	12	5	5	5	5	15	15	15	15	15	15	15	15
Thermal Resistance (m^2K/W)	$\bar{x}$	0.11	0.15	0.14	0.08	0.08	0.06	0.09	0.12	0.12	0.14	0.06	0.09	0.11
	σ	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
		3	3	3	3	3	3	3	3	3	3	3	3	3

* Mass of down plus shell fabric was 545 g/m^2 with σ = 44.

$\bar{x}$ = mean N = number of specimens

σ = standard deviation n = number of measurements

TABLE II

Derived Values

	Down-and-Feathers	Thinsulate				Polarguard					Hollofil		
		M53C	M400	M200	CS150	1	2	3	4	5	1	2	3
Measured at Pressure of 0.16 kPa													
Thermal Resistance Per Unit Mass x10^3 (m^{2}K/W per g/m^2)	1.7	0.50	0.62	0.60	0.91	2.3	1.8	1.8	1.8	1.7	1.6	1.9	1.7
Thermal Resistance Per Unit Thickness (m^{2}K/W per mm)	0.029	0.032	0.032	0.034	0.031	0.022	0.020	0.019	0.018	0.020	0.025	0.022	0.022
Measured at Pressure of 7.76 kPa													
Thermal Resistance Per Unit Mass x10^3 (m^{2}K/W per g/m^2)	0.32	0.28	0.35	0.40	0.46	0.52	0.41	0.47	0.44	0.47	0.32	0.35	0.31
Thermal Resistance Per Unit Thickness (m^{2}K/W per mm)	0.032	0.029	0.033	0.040	0.053	0.055	0.041	0.035	0.032	0.038	0.055	0.043	0.042

3. The thermal resistance per unit thickness at the lower pressure is greater for down-and-feathers and the Thinsulates than for Polarguard and Hollofil.

4. At the higher pressure of 7.76 kPa, the thermal resistance per unit mass or per unit thickness for all the insulants is much the same.

PART 2 - THE EFFECT OF LAUNDERING ON INSULATING MATERIALS

MATERIALS

The insulants used for the laundering tests were Thinsulate M200, Thinsulate CS150, Polarguard #5 (295 g/m^2), Hollofil #2 (260 g/cm^2) and the down-and-feathers. Three 30 cm square specimens of each insulant were prepared. The synthetic insulants were enclosed in a nylon taffeta bag (100 g/m^2). The nylon taffeta is the shell fabric of the current Canadian Forces sleeping bag. Five centimeters in from two opposite edges, seams were sewn to hold the battings in place in much the same manner that the baffles in the CF down-and-feathers sleeping bag keep their contents in place. Schematic drawings of the specimens construction are shown in Figure 1. As in Part 1, the down-and-feathers specimens were stitched around the perimeter, then cut from a new CF sleeping bag. A binding was then sewn around the edges of these specimens. However, after Wash 5, it was necessary to add extra binding and zigzag stitching around the edges of the down-and-feathers to prevent the down and the feathers from escaping during laundering. Because of the rather peculiar results after this was done, one more specimen of the down-and-feathers was made with extra binding and zigzag stitching and tested over the 40 washes.

TEST PROCEDURES

LAUNDERING

Before each laundering, dry towels were added to the specimens to make up a total weight of 1800 g. The specimens and the towels were then laundered in a Maytag washing machine, Model A308. Details of the laundering cycle are given in Table III. The water temperature was about 51°C for the wash cycle and about 8°C for the rinse cycle. For each wash, 185 g of "ALL" laundry detergent was added. The specimens and towels were dried in a Maytag

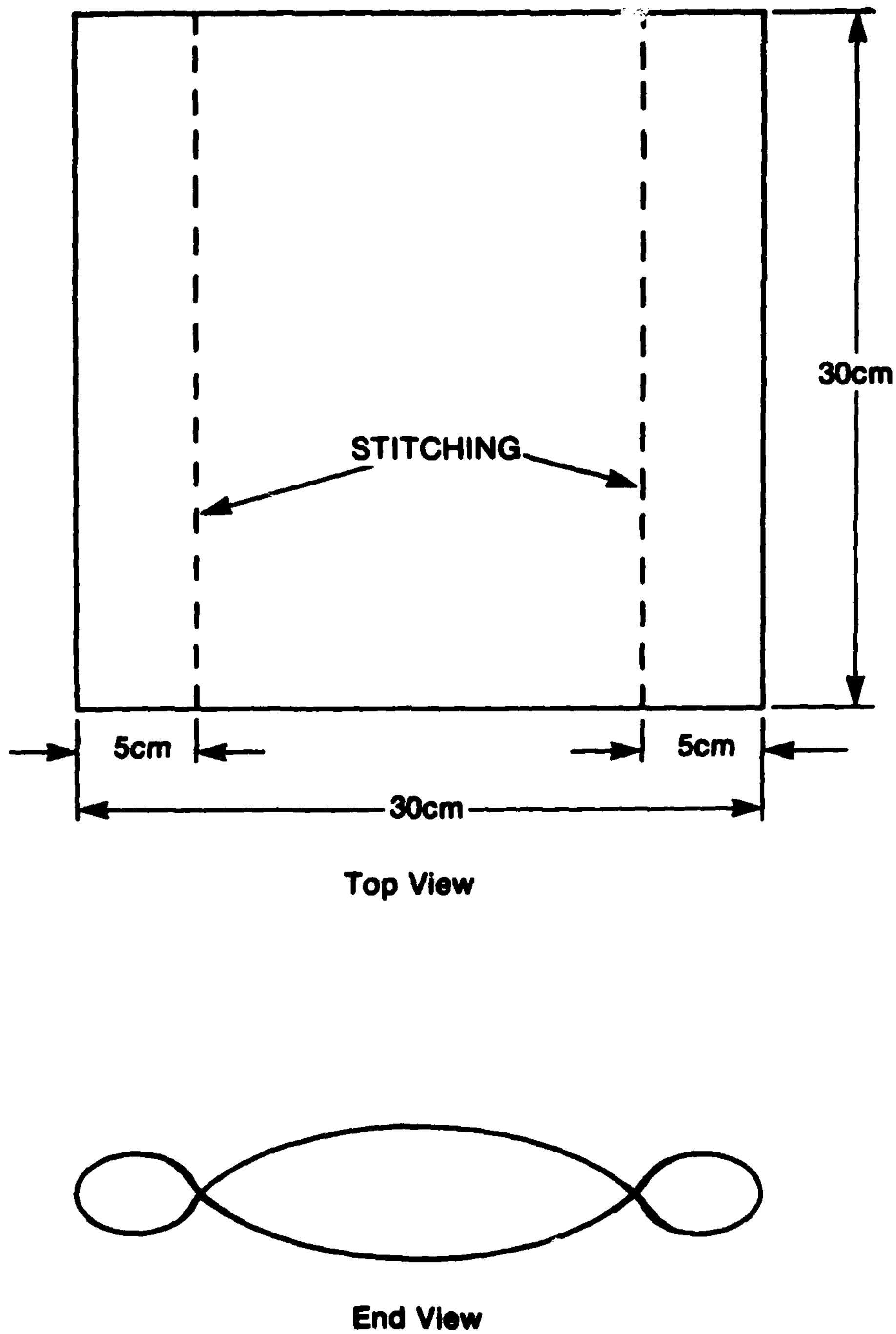


Fig. 1: Top Edge View of Specimens.

TABLE III

Details of the Wash Cycle

Action	Time (min)
Fill	3.5
Wash	9.0
Pause	1.0
Spin and Rinse	2.0
Spray Rinse	1.0
Spin and Drain	1.0
Fill	3.5
Deep Rinse	2.0
Pause	1.0
Damp Dry	5.0
Total	29.0

dryer, Model DE 18CA, Series 02 for about 45 minutes with a final exhaust-air temperature of 60°C.

MEASUREMENT OF PERTINENT PHYSICAL PROPERTIES

The pertinent physical properties selected to be measured were compression and recovery, thickness and thermal resistance.

The compression and recovery measurements were made according to the method described in Part 1. Because of the seaming on the specimens, some of the specimens were puffed up in the middle (Polarguard and Hollofil). Also, on washing, some of the specimens became thick and lumpy. Therefore it was necessary to modify the C&R Tester to accommodate these specimens since the Tester only had a 2.5 cm travel. Depending on the thickness of the specimen, either a 1.5 or a 2.5 cm spacer was inserted between the base and the frame of the Tester. This increased the range of the Tester by a constant value, but did not alter the 2.5 cm travel. When a greater travel than this was necessary between the pre-load thickness (P) and the major load (M), it became necessary to alter the method slightly by measuring the P value first with the appropriate spacer in place and then the remaining values with the spacer removed. Five sets of measurements were made on each specimen.

The thickness measurements were also carried out as described in Part 1, but at pressures of 0.16, 0.33, 0.50, 0.67 and 0.86 kPa, the range available with the 64.5 cm^2 foot and the loading weights. Because of the puffed-up shape of some of the specimens, and because of the large 64.5 cm^2 foot, it was not possible to take the standard five readings on all the specimens. Four readings per specimen were made on the Thinsulate M200 and CS150 and the down-and-feathers. Two readings per specimen were made on the Polarguard and the Hollofil. Again, the appropriate spacer was inserted into the C&R Tester as required.

Thermal resistance measurements were made with a Dynatech "Rapid K" Thermal Conductivity Instrument. These measurements were made at the mean thicknesses as measured at each of the following pressures: 0.16, 0.50 and 0.86 kPa. Each specimen was placed individually in the instrument, the spacing between the plates adjusted to the appropriate thickness and the instrument allowed to reach thermal equilibrium. Readings were then taken and a value calculated for R, the thermal resistance.

All of the above measurements were made initially on the unwashed specimens and then after one, five, ten, twenty and forty washes, with the exception that after the initial set of compression and recovery measurements, one representative specimen of each insulant was tested for compression and recovery.

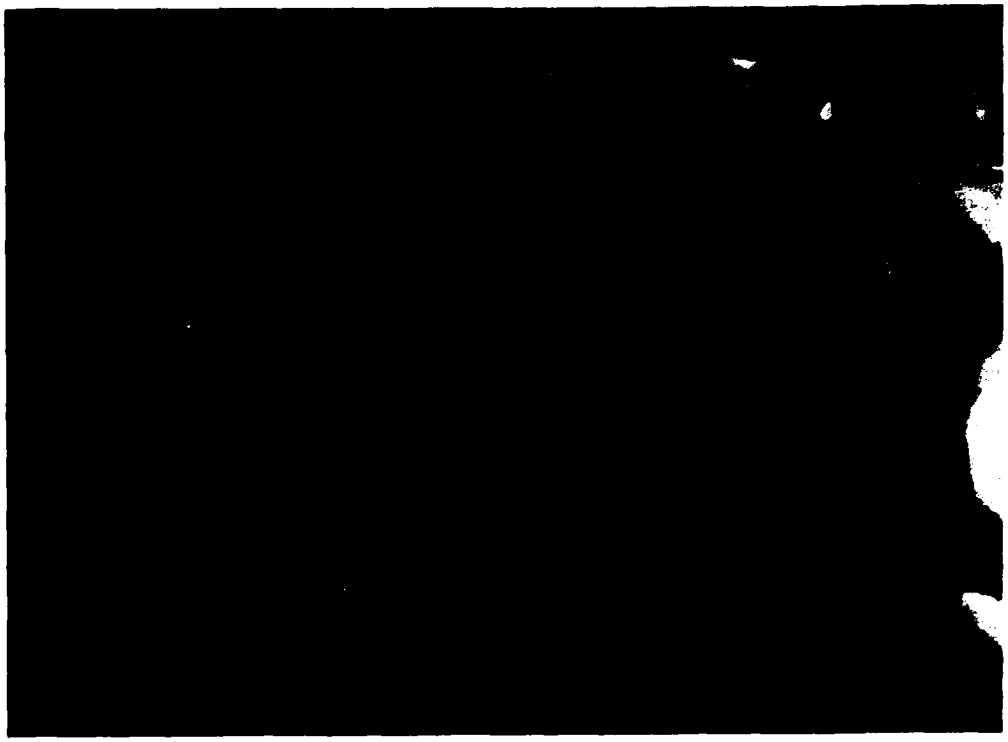
RESULTS

Photographs of the insulants, before and after the 40 washes are in Figures 2 to 7. Hollofil was the most severely affected by washing, forming hard matted balls of fibres. This matting was first observed after Wash 5 and is shown in Figure 8. The photograph was taken with the Hollofil specimen placed over a light source. The visual appearance of the Polarguard and the Thinsulate specimens did not change very much. The Thinsulate specimens took on the appearance of washed flannelette. Most of the down-and-feathers broke into smaller pieces, with only a few of the feathers staying intact.

The values of thermal resistance, R, at various pressures and aft· · various washings are given in Table IV and presented graphically in F. :s 9 to 13. Error bars are given when they are of sufficient length to be . ,resented on the graph. The R-values at 0.50 and 0.86 kPa for all insulants follow a similar but less pronounced pattern of the R-values at 0.16 kPa, and so will not be discussed in detail.

The behaviour of the two Thinsulates, M200 (Figure 10) and CS150 (Figure 11), was similar. Their R-values decreased the most from Wash 0 to Wash 5, with a gradual decrease thereafter. After Wash 40, the thermal resistance of M200 had decreased 30% from its original unwashed value, and that of CS150, 37%, both at 0.16 kPa pressure. The thermal resistance of Polarguard (Figure 12) also decreased gradually as the number of washes increased, with an overall decrease in thermal resistance of 20% after Wash 40 (at 0.16 kPa). The thermal resistance of Hollofil (Figure 13) increased after Wash 1, probably due to the fluffing up of the staple fibre during the first drying cycle. The thermal resistance of this insulant then decreased through the 40 washes (35% decrease at 0.16 kPa). It is interesting to note that there is very little difference in the thermal resistance as measured at 0.16, 0.50 and 0.86 kPa after the 40 washes. By this time, the batting had matted into such hard balls that these increases in pressure had very little effect on the specimen thickness, and thus the thermal resistance.

The thermal resistance of the down-and-feathers (Figure 9) decreased from Wash 0 to 1, probably because, as with Hollofil, the specimens had been fluffed up in the dryer. The thermal resistance decreased from Wash 1 to Wash 5 and then increased to approximately the same value as for Wash 1 after Wash 10. At the time, it was thought that the loss of a few feathers and bits of down from the three specimens during the wash cycle was responsible for the decrease in thermal resistance from Wash 1 to 5, and that the addition of a binding around each specimen after Wash 5 had increased the effective thickness and thus the thermal resistance of the down-and-feathers specimens. To check whether this was in fact the case, an additional down-and-feathers specimen was made, as described earlier, and put through 40 washes. No down or feathers were observed to have escaped



After *Before*

Fig. 2: Down and Feathers Before and After 40 Washes.

Before *After*

Fig. 3: M200 Before and After 40 Washes.

Before *After*

Fig. 4: CS150 Before and After 40 Washes (scrim side out).

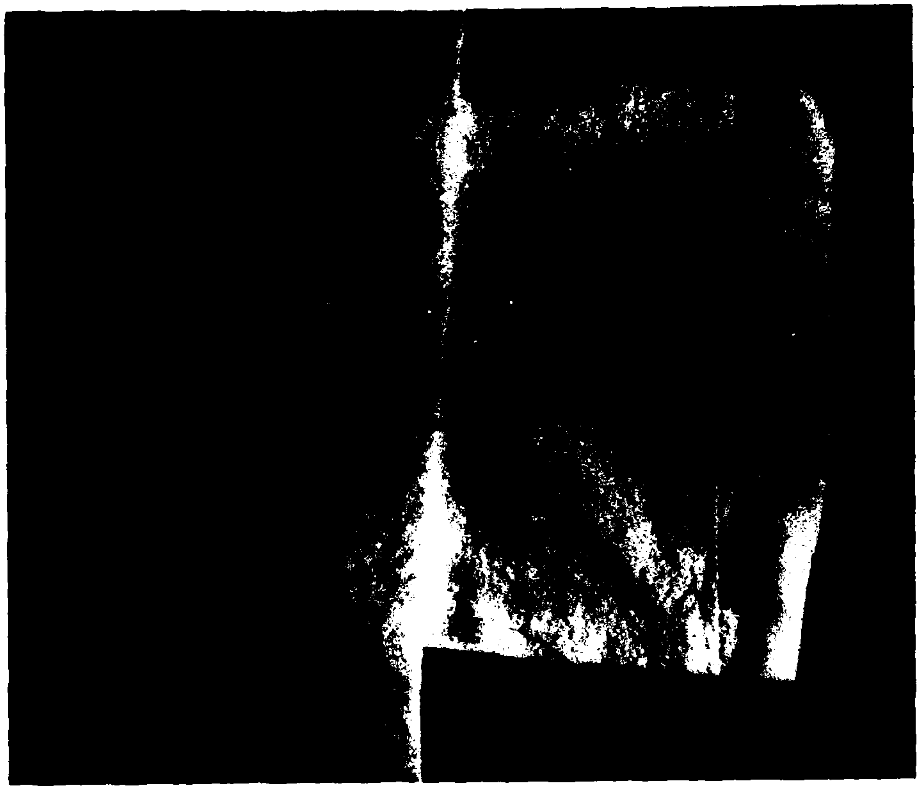
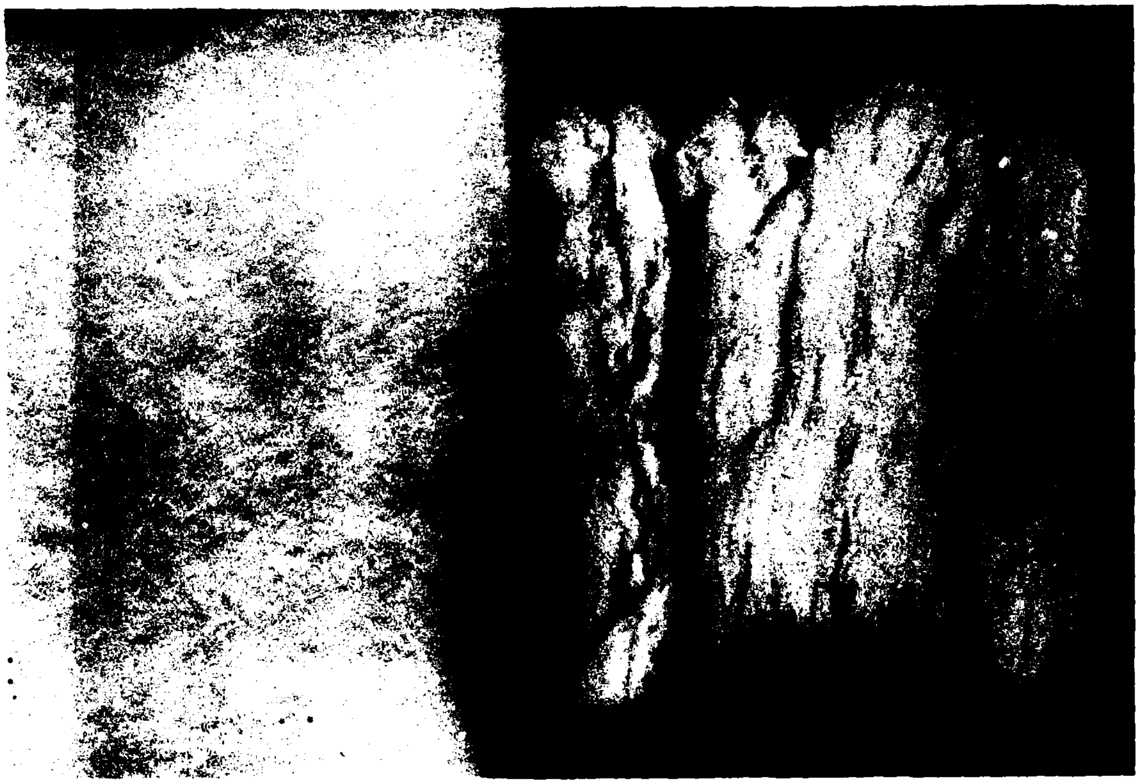


Fig. 5: CS150 Before and After 40 Washes (uncovered side out).



Before *After*

Fig. 6: Polarguard Before and After 40 Washes.

Before After

Fig. 7: Hollofil Before and After 40 Washes.

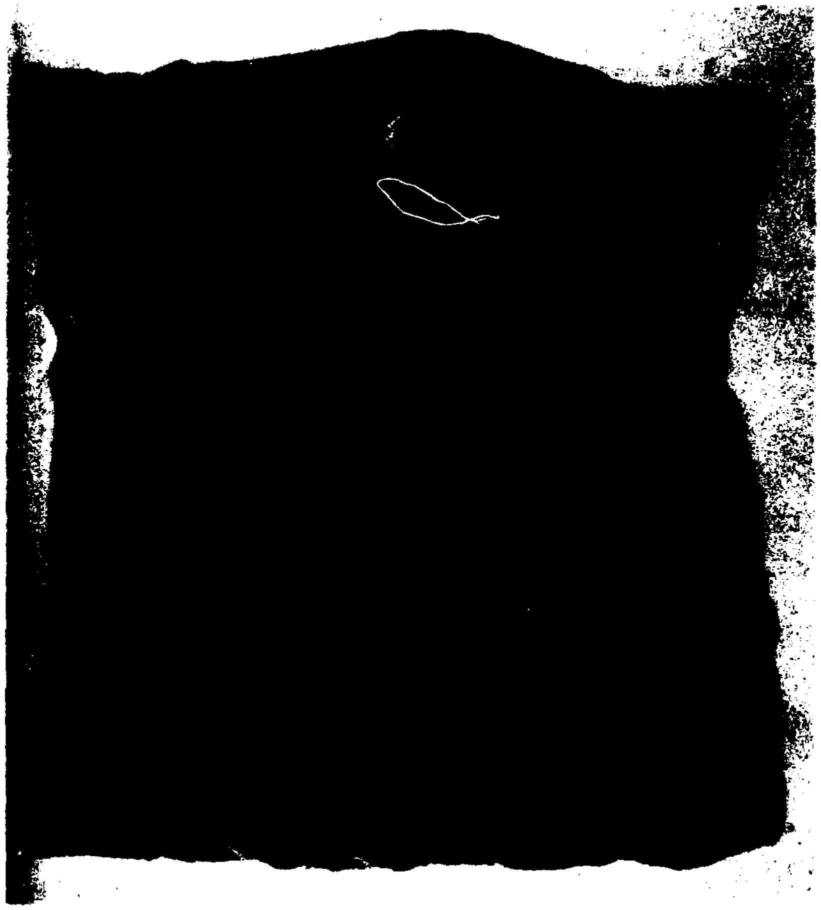


Fig. 8: The Clumping and Matting of Hollofil Specimen After 5 Washes.

TABLE IV

Mean R Values at Various Pressures and Washes (m^2K/W)
(CV is the coefficient of variation in %)

Batting	Pressure kPa		Number of Washes					
			0	1	5	10	20	40
Thinsulate M200	0.16	R	0.15	0.14	0.12	0.11	0.12	0.10
		CV	1.8	1.1	1.0	0.88	0.47	0.57
	0.50	R	0.11	0.11	0.09	0.09	0.10	0.08
		CV	1.1	0.94	2.9	0.68	1.5	1.5
	0.86	R	0.10	0.09	0.08	0.08	0.09	0.07
		CV	1.7	1.3	0.70	0.00	1.2	0.79
Thinsulate CS150	0.16	R	0.20	0.19	0.15	0.14	0.14	0.12
		CV	4.4	0.54	1.4	1.2	2.0	1.7
	0.50	R	0.14	0.13	0.11	0.10	0.11	0.09
		CV	0.82	0.43	4.5	2.1	1.1	3.6
	0.86	R	0.12	0.11	0.10	0.09	0.10	0.08
		CV	0.85	2.4	3.7	2.0	2.7	3.4
Polarguard #5	0.16	R	0.75	0.75	0.70	0.70	0.66	0.61
		CV	1.6	0.62	2.7	5.5	6.0	1.6
	0.50	R	0.64	0.62	0.59	0.56	0.53	0.50
		CV	1.1	2.6	3.4	3.8	3.1	0.30
	0.86	R	0.57	0.54	0.51	0.49	0.46	0.46
		CV	0.44	2.9	2.3	2.6	3.7	2.3
Hollofil #2	0.16	R	0.80	0.91	0.82	0.77	0.70	0.52
		CV	1.4	6.4	6.5	4.1	8.3	11
	0.50	R	0.66	0.73	0.68	0.60	0.56	0.46
		CV	1.2	2.6	3.8	3.4	5.6	14
	0.86	R	0.52	0.56	0.57	0.53	0.48	0.41
		CV	1.5	1.4	2.9	0.61	2.7	12
Down-and-Feathers	0.16	R	0.60	0.68	0.55	0.67	0.65	0.62
		CV	1.1	3.5	5.1	1.3	5.1	0.94
	0.50	R	0.36	0.39	0.36	0.39	0.35	0.36
		CV	1.4	4.0	0.43	1.6	0.57	1.0
	0.86	R	0.27	0.29	0.27	0.30	0.26	0.26
		CV	2.2	3.2	2.9	1.4	0.80	2.2
Additional Specimen	0.16	R	0.75	0.76	0.57	0.47	0.64	0.58
	0.50	R	0.44	0.44	0.31	0.30	0.43	0.40
	0.86	R	0.30	0.31	0.21	0.24	0.32	0.31

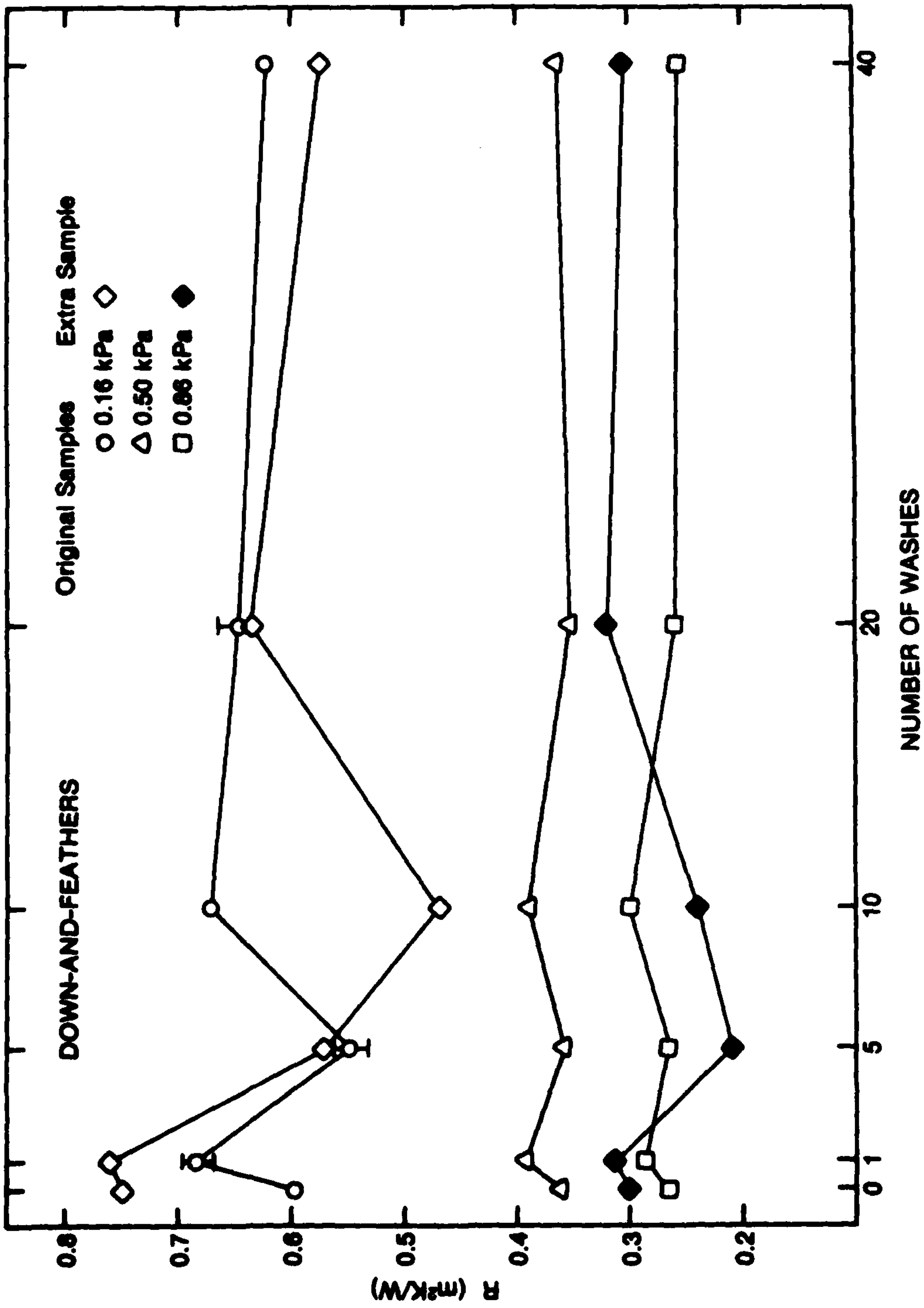


Fig. 9: The Effect of Laundering on the Thermal Resistance (R) of Down-and-Feathers.

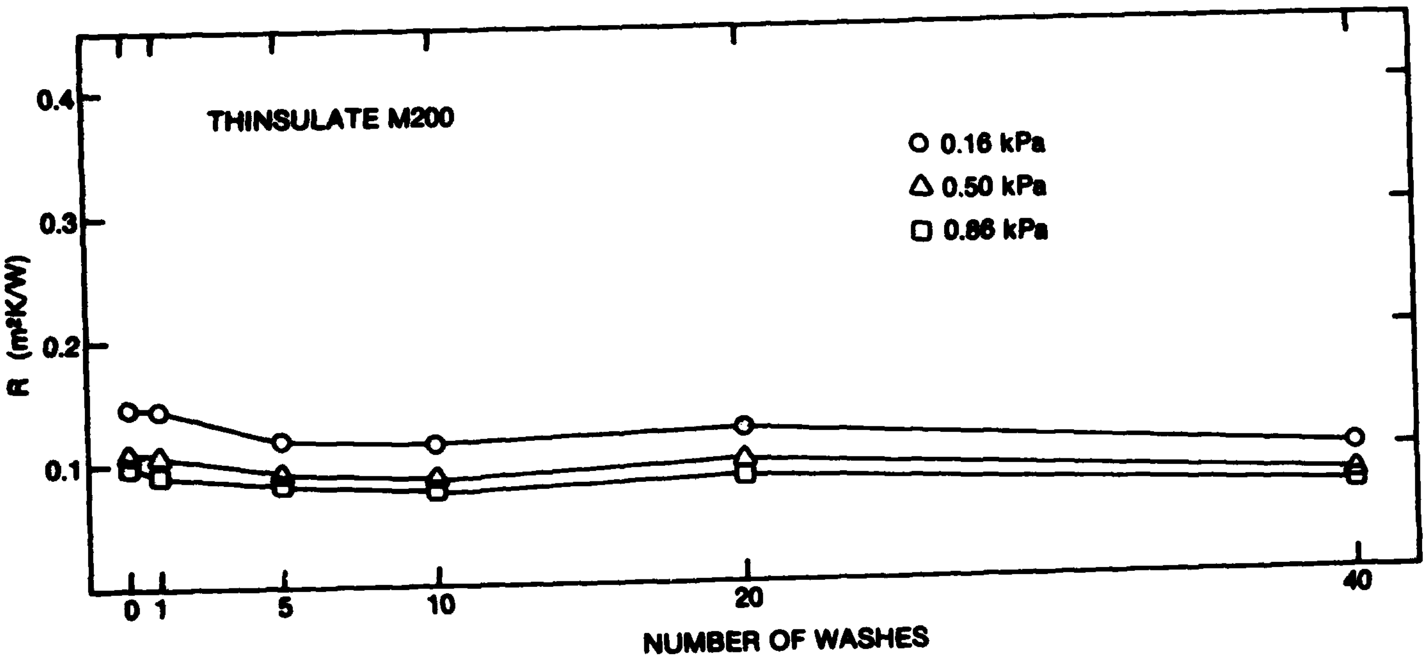


Fig. 10: The Effect of Laundering on the Thermal Resistance (R) of Thinsulate M200.

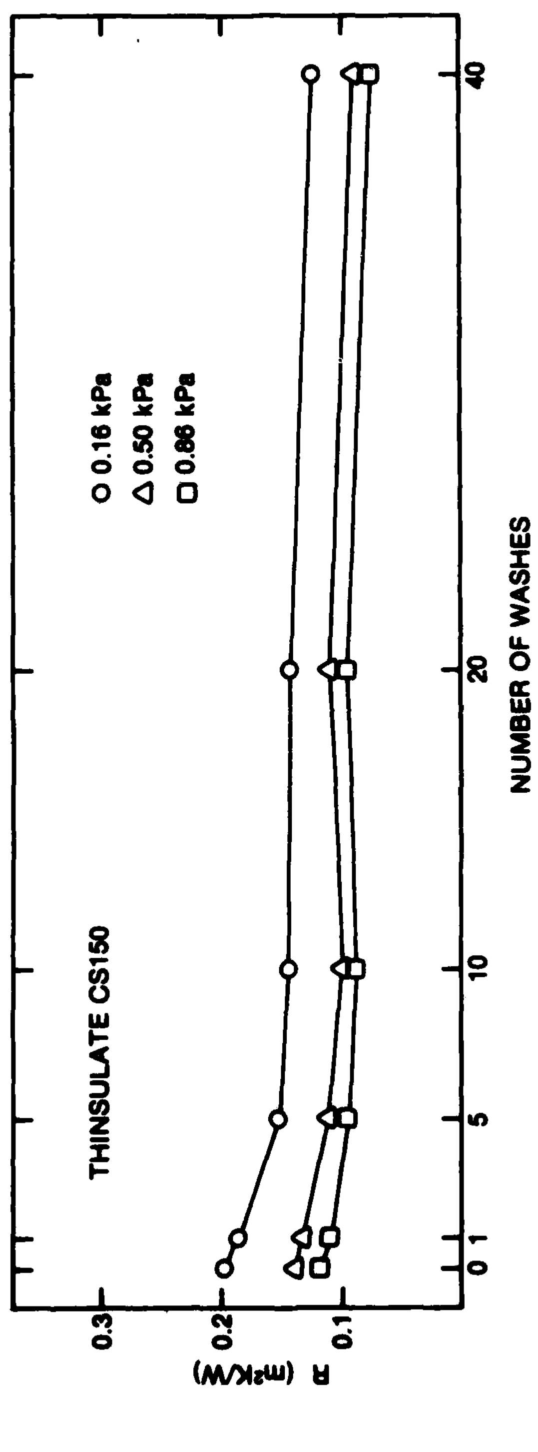


Fig. 11: The Effect of Laundering on the Thermal Resistance (R) of Thinsulate CS150.

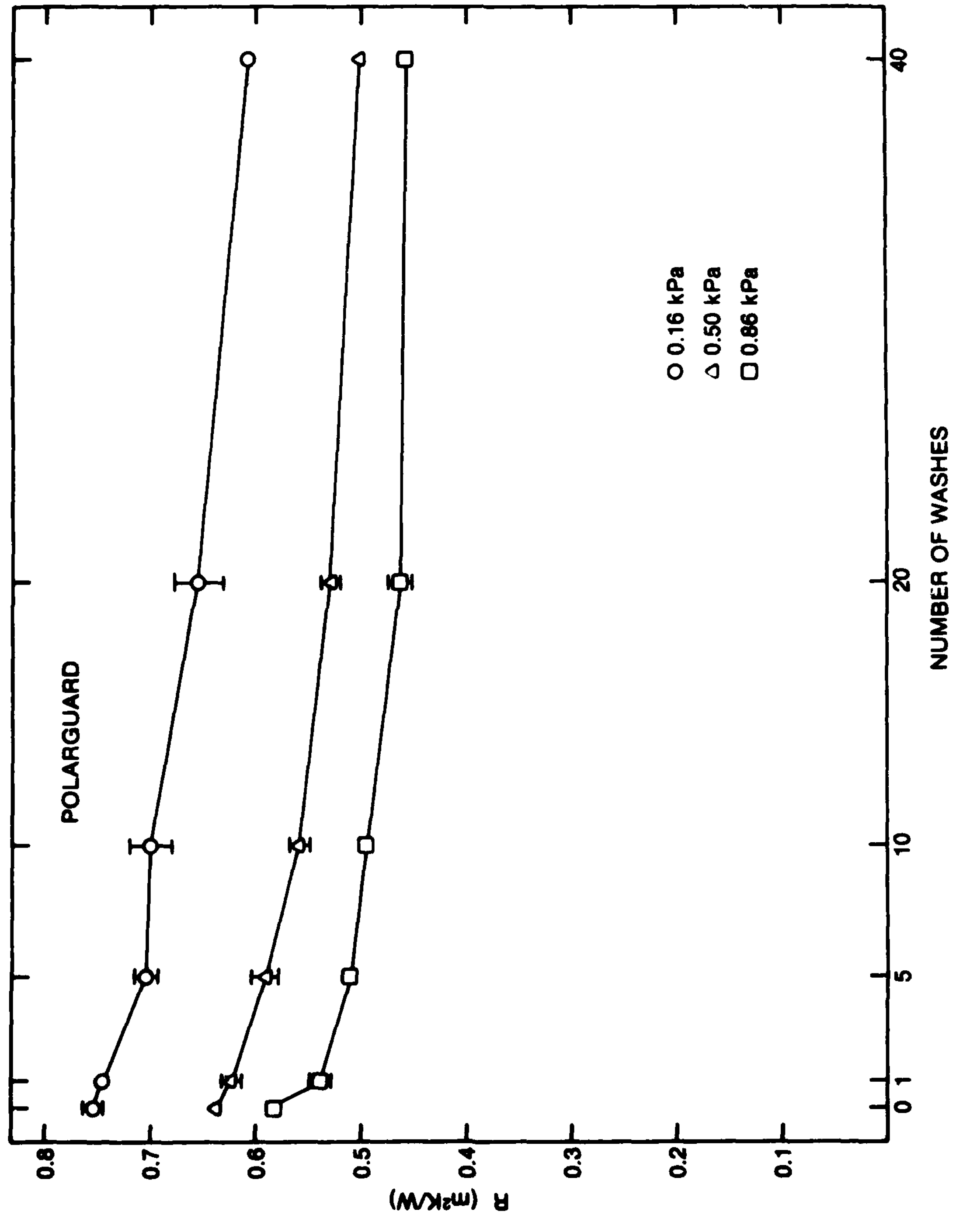


Fig. 12: The Effect of Laundering on the Thermal Resistance (R) of Polarguard.

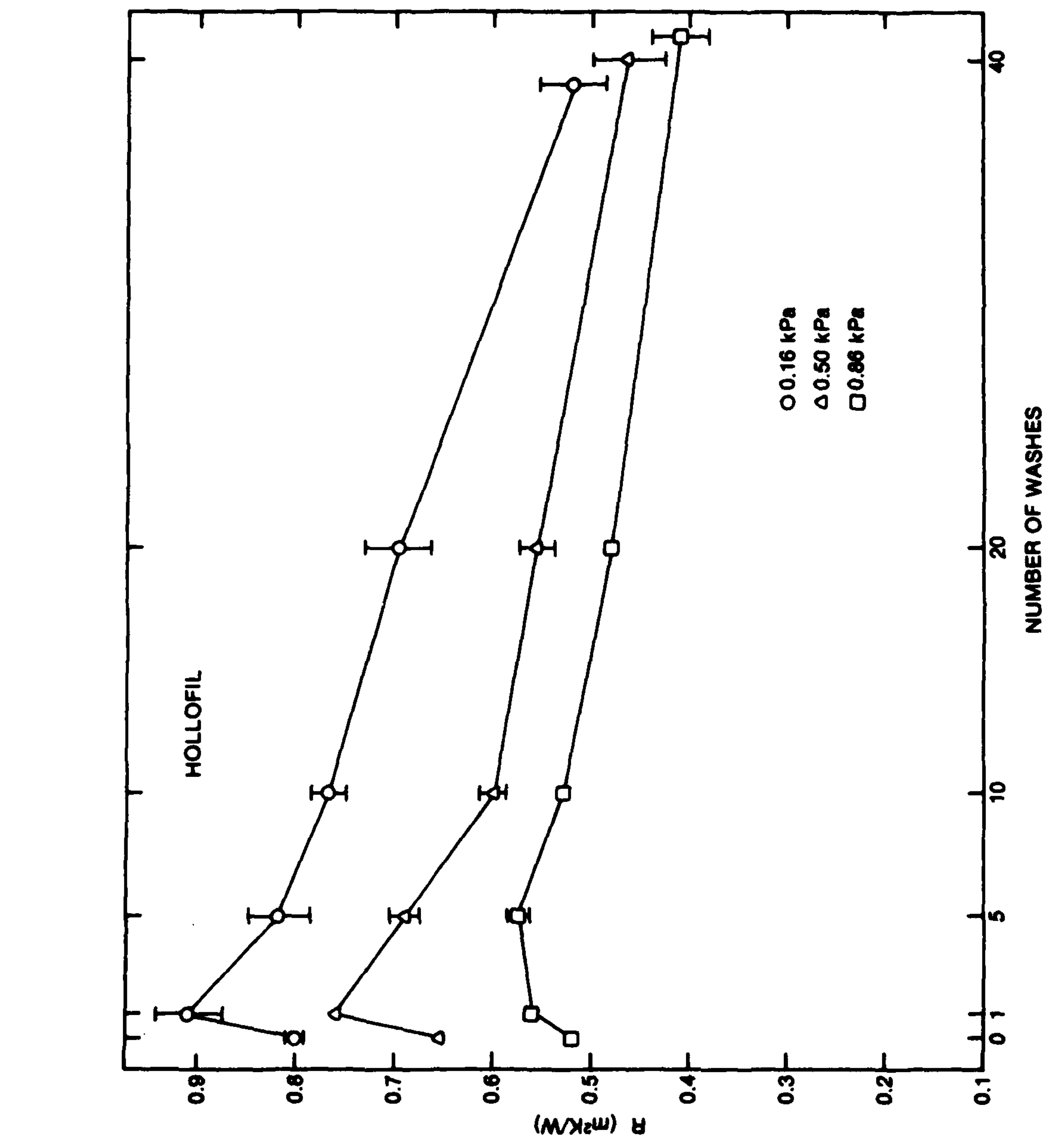


Fig. 13: The Effect of Laundering on the Thermal Resistance (R) of Hollofil.

from this specimen. However, this specimen also displayed the increase-decrease-increase pattern in thermal resistance of the original three specimens, reaching a *minimum* between Wash 5 and 10, rather than between Wash 1 and 5 as described for the original three specimens.

Two reasons for this behaviour were postulated. First it was thought that the down-and-feathers might contain sufficient natural oil to keep them initially in a "dampened" condition, and once this oil was removed by washing, the down-and-feathers would become more buoyant and fluffy, thus increasing the loft and thus the thermal resistance of the specimens.

A sample of down-and-feathers was taken from a new CF sleeping bag and distilled with carbon tetrachloride which would remove any oils from the down and feathers. No measurable change in weight of the sample before and after distillation could be detected, indicating that the amount of oil on the down-and-feathers is minimal and thus would not be responsible for the fluctuations in thermal resistance.

The second reason postulated for the fluctuations is that the barbs on the shafts of the feathers are eventually broken off by the combination of alkaline (detergent) attack and the mechanical actions of washing, spin drying and tumble drying. These broken barbs are similar to down and may act as down to give loft to the specimens, and thus increase the thermal resistance of the specimen. Prior to the barbs breaking off the feather shaft, they may begin to crack slowly where they join to the shaft, thus reducing the resiliency of the feather and thus the loft and the thermal resistance.

A third set of down-and-feathers specimens were washed 40 times with no detergent added to the wash water. Because there was no detergent to wet out the specimens and because of the inherent buoyancy of the specimens, the specimens floated on the surface of the wash water for all 40 washes. Therefore it is questionable whether they received the same mechanical action of the first set of specimens. After the 40 washes, there was no visual difference in the washed down-and-feathers and the unwashed down-and-feathers. No further work was done at this time since the purpose of this study was to find a substitute for down-and-feathers.

After Wash 10 there was essentially no change in thermal resistance of the first three down-and-feathers specimens, with the thermal resistance after 40 washes being the same as the original unwashed thermal resistance.

After Wash 20, the thermal resistance of the additional down-and-feathers specimen did not quite reach its original thermal resistance as measured at 0.16 kPa, but did so at 0.50 and 0.86 kPa. It had a slight decrease in thermal resistance at all three pressures after Wash 40.

To compare the relative effects of laundering on the five insulating materials, their thermal resistances, as measured at 0.16 kPa pressure, are plotted (without error bars) on the same graph, Figure 14.

The mean thicknesses at 0.16 and 0.86 kPa at the various numbers of washes are given in Figures 15 to 17. As expected, the changes in thickness with laundering follow much the same pattern as the changes in thermal

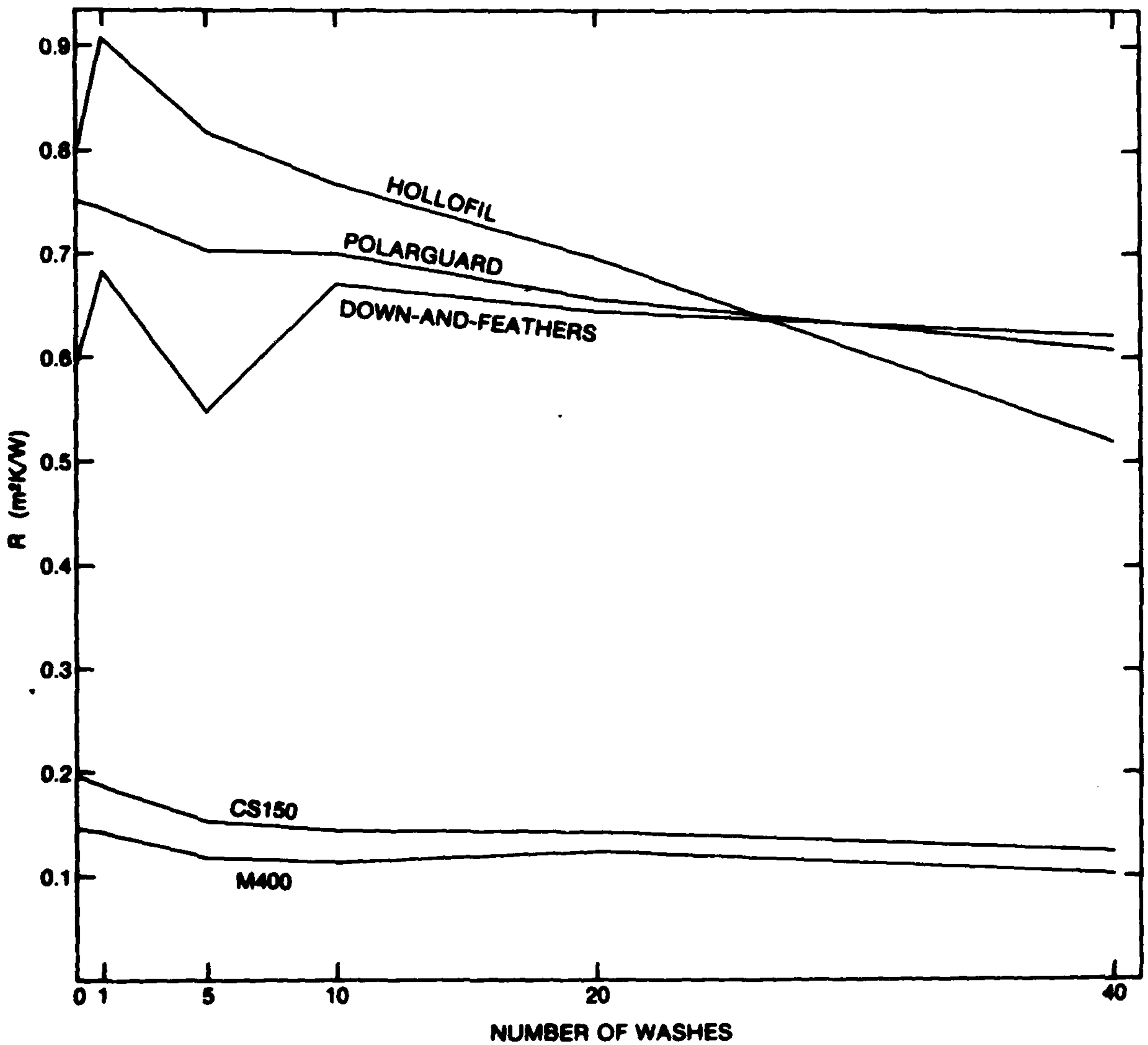


Fig. 14: The Relative Effect of Washing on the Thermal Resistance (Measured at 0.16 kPa Pressure) on the Insulants.

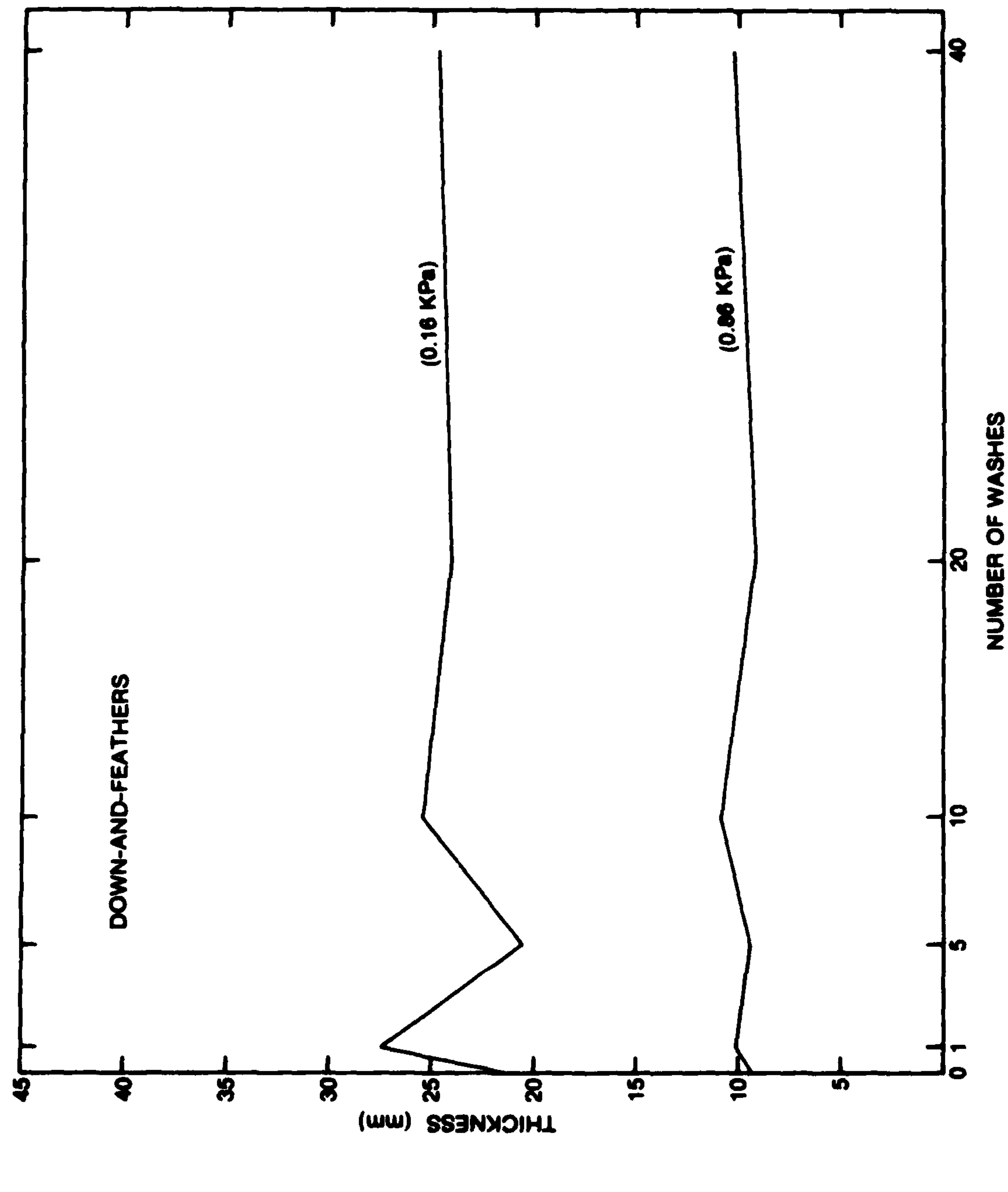


Fig. 15: The Effect of Laundering on the Thickness of Down-and-Feathers.

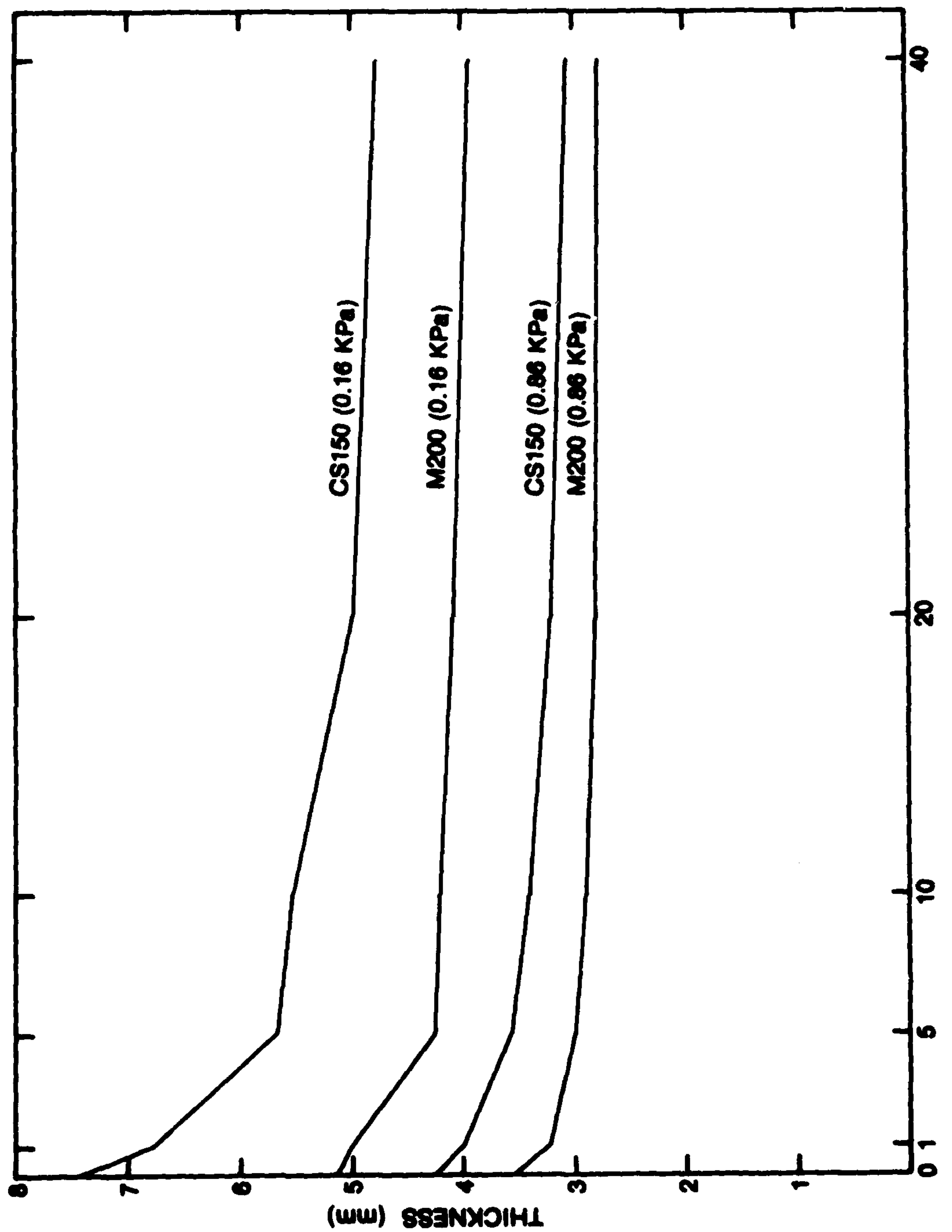


Fig. 16: The Effect of Laundering on the Thickness of M200 and CS150.

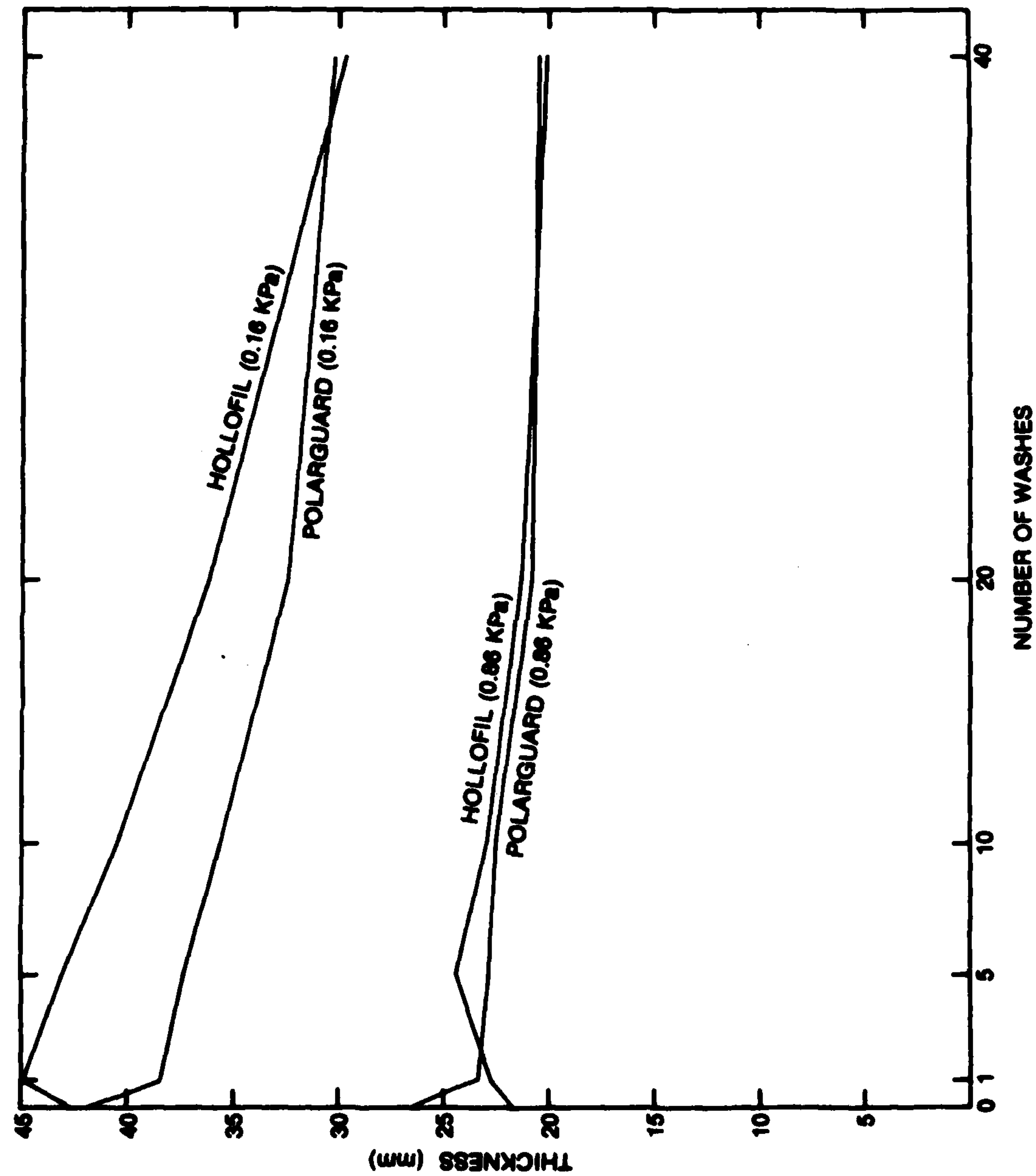


Fig. 17: *The Effect of Laundering on the Thickness of Polarguard and Hollofil.*

resistance. The thickness of the two Thinsulates decreased the most from unwashed to Wash 10, the thickness of CS150 dropping off more quickly than that of M200. The thickness of Polarguard decreased steadily, its sharpest decrease was from unwashed to Wash 1. As with its thermal resistance, the thickness of Hollofil increased from unwashed to Wash 1 and then steadily decreased to Wash 40. The thickness of the down-and-feathers also followed the same pattern as its thermal resistance, with an increase-decrease-increase pattern.

The actual values of thickness versus pressure and of compressibility and recovery after the various numbers of washes are given in Tables V and VI. In the thickness versus pressure table, Table V, the slope of the line, A, (for the equation $\log y = Ax + B$ where y is the thickness and x is the pressure) is given. The change in A gives a good indication of the change in compressibility with washing, the higher the value of A, the more compressible the specimen over the pressure range of 0.16 to 0.86 kPa.

On washing, the compressibility of Polarguard and the down-and-feathers did not change substantially at low loads (0.16 to 0.86 kPa) or at the high load of 7.76 kPa. Washing did not change the compressibility of M200 greatly at low loads, but it became less compressible at the high loading. CS150 and Hollofil became less compressible at both the high and low loads, the Hollofil more so than the CS150.

The % recovery of M200 and CS150 increased with washing, that of the down-and-feathers, Polarguard, and Hollofil decreased after Wash 1, increasing again by Wash 40. It is noted that although the % recovery may increase, the actual recovery of the specimen may be lower since the recovery is expressed as a percent of the compression.

CONCLUSIONS

1. Hollofil should not be used in an item if it requires laundering.

2. Although Polarguard and Thinsulates Type "M" and "CS" retain their integrity with washing, there is a decrease in their thermal resistance on laundering.

3. Because of the behaviour of down-and-feathers on washing, special care should be taken in washing this insulant, i.e. gentler washing in a mild, rather than a strong detergent.

TABLE V

The Effect of Washing on the Thickness of the Insulants as Measured at Five Pressures

Thickness (mm)

	Pressure kPa	Number of Washes 0	1	5	10	20	40
Down-and-Feathers	0.16	21.7	27.6	20.6	25.5	24.1	24.8
	0.33	16.5	20.1	15.8	19.3	16.5	18.4
	0.50	12.6	14.4	13.0	14.3	12.6	13.7
	0.67	10.9	11.7	10.8	12.4	10.5	11.6
	0.86	9.5	10.2	9.4	10.9	9.2	10.3
	A*	-0.52	-0.64	-0.49	-0.54	-0.60	-0.56
Thinsulate M200	0.16	5.1	5.0	4.2	4.2	4.1	3.9
	0.33	4.3	4.0	3.6	3.5	3.4	3.4
	0.50	3.9	3.7	3.4	3.3	3.2	3.1
	0.67	3.7	3.4	3.1	3.1	2.9	2.9
	0.86	3.5	3.2	3.0	2.9	2.8	2.8
	A	-0.23	-0.27	-0.21	-0.22	-0.23	-0.21
Thinsulate CS150	0.16	7.4	6.8	5.7	5.5	5.0	4.8
	0.33	5.9	5.4	4.7	4.4	4.1	3.9
	0.50	5.1	4.8	4.2	3.9	3.7	3.5
	0.67	4.6	4.3	3.8	3.7	3.4	3.2
	0.86	4.2	4.0	3.6	3.4	3.2	3.0
	A	-0.35	-0.32	-0.29	-0.30	-0.27	-0.21
Polarguard #5	0.16	41.8	38.4	37.3	35.6	32.4	30.2
	0.33	35.8	33.0	31.1	29.7	28.0	26.3
	0.50	32.0	28.9	27.8	26.3	24.4	23.7
	0.67	29.0	26.4	24.9	23.7	22.3	22.0
	0.86	26.5	23.4	22.8	22.5	20.8	20.5
	A	-0.28	-0.31	-0.30	-0.29	-0.28	-0.24
Hollofil #2	0.16	42.8	45.0	43.1	40.6	36.2	29.8
	0.33	35.7	37.6	35.8	31.7	30.6	26.6
	0.50	30.7	31.8	31.8	27.3	25.7	24.5
	0.67	26.4	28.7	26.2	24.0	23.3	22.8
	0.86	21.8	22.8	24.4	22.8	21.3	20.2
	A	-0.42	-0.41	-0.37	-0.36	-0.34	-0.24

* A is the slope of the thickness vs log pressure line.

TABLE VI

The Effect of Washing on the % Compressibility (C) and % Recovery (Re) of the Insulants

		Number of Washes					
		0	1	5	10	20	40
Down-and-Feathers	C	80.5	79.4	78.9	76.9	77.3	76.1
	Re	37.5	33.2	35.6	33.7	37.0	39.9
Thinsulate M200	C	35.1	33.6	29.7	28.1	28.5	25.3
	Re	44.1	43.9	47.3	48.7	47.0	52.2
Thinsulate CS150	C	59.4	56.3	52.3	48.9	45.7	42.3
	Re	44.3	44.0	47.1	49.7	56.1	55.3
Polarguard #5	C	68.8	71.5	68.8	68.0	66.4	60.1
	Re	35.7	29.2	29.0	29.8	31.7	35.4
Hollofil #2	C	81.7	83.0	73.6	77.8	76.8	63.0
	Re	36.1	30.7	32.2	28.0	26.3	34.4

PART 3 - PHYSIOLOGICAL EVALUATION OF INSULATING MATERIALS FOR SLEEPING BAGS

Based on initial physical tests of several different synthetic insulating materials, a number of prototype sleeping bags was manufactured using the candidate insulants and the same pattern and shell fabric as the currently-used CF sleeping bag. Each of these was manufactured using a quantity of insulation selected to provide approximately the same thermal protection as the current CF bag. These were identified as follows:

DCGEM Exp. No.	DREO Exp. No.	Insulating Material
	A	Current CF sleeping bag: down-and-feathers
X79-012	B	Hollofil #350
X79-013	C	Laminate of Polarguard #220 and #115
X79-014	F	Laminate of 2 layers Polarguard #115
X79-015	G	Laminate of 2 layers Polarguard #220
X79-017	H	Polarguard #255
X79-018	D	Thinsulate CS-300B
X79-021	E	Polydown 50/50 - polyester/down to same filling weight as current Arctic inner bag

Because of operational and supply difficulties, the physiological evaluation of the sleeping bags was conducted in two phases at different times of the year (May-June and November-December). For the first phase, one sleeping bag made using each of the different types of insulating materials was selected and compared to the in-service CF down/feather sleeping bag. During the second phase of the evaluation, bags manufactured using different combinations of the same insulant (Polarguard) were compared to the CF sleeping bag.

METHOD OF TEST

Four members of the CF/DREO Test Team volunteered to participate in the evaluation. They were active, male military personnel from the Combat Arms trades of the Canadian Forces. Their physical characteristics are given in Table VII. All of the participants had had previous experience in using

the CF Arctic sleeping bag.

TABLE VII

Physical Characteristics of Test Subjects

Subject No.	Age (years)	Height (cm)	Weight (kg)
1	44	177	81
2	38	172	72
3	23	175	64
4	21	176	93

The comparative evaluation was conducted over a period of several weeks using the four subjects who rested in the DREO cold chamber for four-hour test sessions at a moderately cold ambient temperature of -23°C. Sleeping bags manufactured using different insulating materials were tested simultaneously. The type of sleeping bag used by each subject was changed on successive days so that by the end of the evaluation, each of the subjects had slept in each type of bag a total of seven times.

In order to simulate field conditions and to reduce the effect of wind caused by the circulation of air from the refrigeration unit, subjects slept in a CF five-man tent erected in the cold chamber. The sleeping bags rested on air mattresses placed on the wooden floor of the chamber inside the tent. The only items of clothing worn by the test subjects while in the sleeping bags were CF extreme-cold-weather drawers and undershirt.

Thermal protection afforded by each type of sleeping bag was assessed in terms of differences in rectal temperature (T_R), chest, arm, leg and great-toe temperatures. These were measured using YSI thermistor probes and were recorded automatically at twenty-minute intervals during each four-hour test session using a Digitec Model 1581 Datalogger. Mean weighted skin temperature (MWST = 0.5 chest temperature + 0.14 arm temperature + 0.36 leg temperature) and total body temperature (T_{TB} = 0.67 T_R + 0.33 MWST) were calculated at selected intervals. Subjective opinions of the test subjects were also noted throughout the evaluation.

The total weight of each sleeping bag was measured at the beginning and end of each test session and the change in weight due to absorption of perspiration was calculated. After every session each sleeping bag was dried in a commercial clothes dryer for a period of twenty minutes.

A method described by Haley and King (3) and used previously by the present authors (4) was used to determine the number of hours of sleep obtained by each of the subjects during test sessions. A hand button was placed inside each sleeping bag and subjects were instructed to press the

button in response to a faint alarm which sounded automatically inside the tent every fifteen minutes. The volume of the alarm was adjusted so that it did not awaken sleeping personnel but could be heard by those not sleeping. Subjects were considered to be asleep during any fifteen minute period in which they did not press the hand button. Pressing the button caused a deflection of one of the pens of a four-channel chart recorder which operated throughout each session.

For each test session the following procedure was used. Subjects reported for duty at approximately 0845 hours, thermistor probes were fitted and the clothing to be worn during the test was donned. Each sleeping bag was then weighed and the subjects entered the cold room at approximately 0915 hours. Technical personnel connected the temperature probes to the recording equipment and lights were turned out. Subjects remained in the cold room for a period of four hours.

RESULTS AND DISCUSSION

A summary of mean results after four hours in the cold chamber at -23°C is given in Table VIII. Each entry represents the mean of 28 measurements and standard deviations are given in brackets. The raw data was analyzed using the techniques of analysis of variance and it was found that differences in T_R, MWST and T_{TB} obtained when the various bags were used were not statistically significant. Results for T_{TOE}, hours of sleep and change in weight were found on analysis to be significantly different but the practical significance of these differences is not clear.

Of the above parameters T_{TOE} is probably the most important due to vasoconstriction and the relationship between body temperature and toe temperature. Each of the mean toe temperatures recorded in Table VIII indicates that the subjects' toes were becoming uncomfortably cold after four hours. (A skin temperature of 30°C is normally considered to be comfortable and marked discomfort starts when skin temperature falls below 20°C.)

Mean number of hours of sleep obtained ranged between 2.2 and 3.0 and interestingly, these minimum and maximum values were obtained when using the sleeping bags in which the minimum and maximum toe temperatures were observed. Although the evaluations were conducted during the day, in general all subjects were able to fall asleep with relative ease and remained asleep for at least 50% of the test period.

The changes in weight or changes in the amount of moisture absorbed during the four hour test period of each type of sleeping bag ranged between 35.6 and 59.0 g. Relative to the average total weight of the sleeping bags (approximately 2.2 kg), the amount of moisture retained by each during the test period is not important.

Mean changes in T_R, MWST and T_{TOE} for each type of sleeping bag used in the second phase of the evaluation are given in Figure 18.

TABLE VIII

Mean Results after Four Hours at -23°C

	Bag* Type	T_R (°C)	MWST (°C)	T_{TB} (°C)	T_{TOE} (°C)	Hours of Sleep (h)	Initial Bag Weight (g)	Change in Weight (g)
1st Phase	A	36.4 (0.4)	34.1 (1.3)	35.6 (0.6)	18.9 (5.2)	2.8 (1.1)	2200	43.2 (11.0)
	B	36.4 (0.4)	34.2 (1.0)	35.7 (0.5)	18.1 (5.3)	2.9 (0.7)	2670	39.3 (11.6)
	C	36.5 (0.4)	34.2 (1.1)	35.8 (0.5)	19.7 (6.2)	2.5 (1.0)	2290	36.9 (8.7)
	D	36.4 (0.5)	33.8 (1.2)	35.6 (0.6)	17.5 (5.4)	2.2 (1.2)	2340	35.6 (9.3)
	E	36.5 (0.3)	33.6 (1.0)	35.5 (0.5)	16.8 (5.8)	2.3 (1.2)	2370	40.2 (12.6)
2nd Phase	A	36.5 (0.4)	34.1 (1.2)	35.7 (0.5)	22.3 (5.9)	2.9 (0.6)	2200	59.0 (10.2)
	F	36.5 (0.3)	34.0 (1.4)	35.7 (0.5)	18.0 (4.5)	2.9 (0.6)	1980	41.6 (7.6)
	G	36.5 (0.3)	34.6 (0.8)	35.9 (0.3)	22.0 (5.7)	3.0 (0.7)	2550	48.6 (8.2)
	H	36.5 (0.3)	33.9 (1.3)	35.6 (0.5)	17.9 (6.3)	2.7 (0.8)	1840	41.7 (9.7)

* A Current CF sleeping bag
B Hollofil #350
C Laminate of Polarguard #220 and #115
D Thinsulate CS-300B
E Polydown 50/50 - polyester/down to same filling as current Arctic inner bag
F Laminate of 2 layers Polarguard #115
G Laminate of 2 layers Polarguard #220
H Polarguard #255

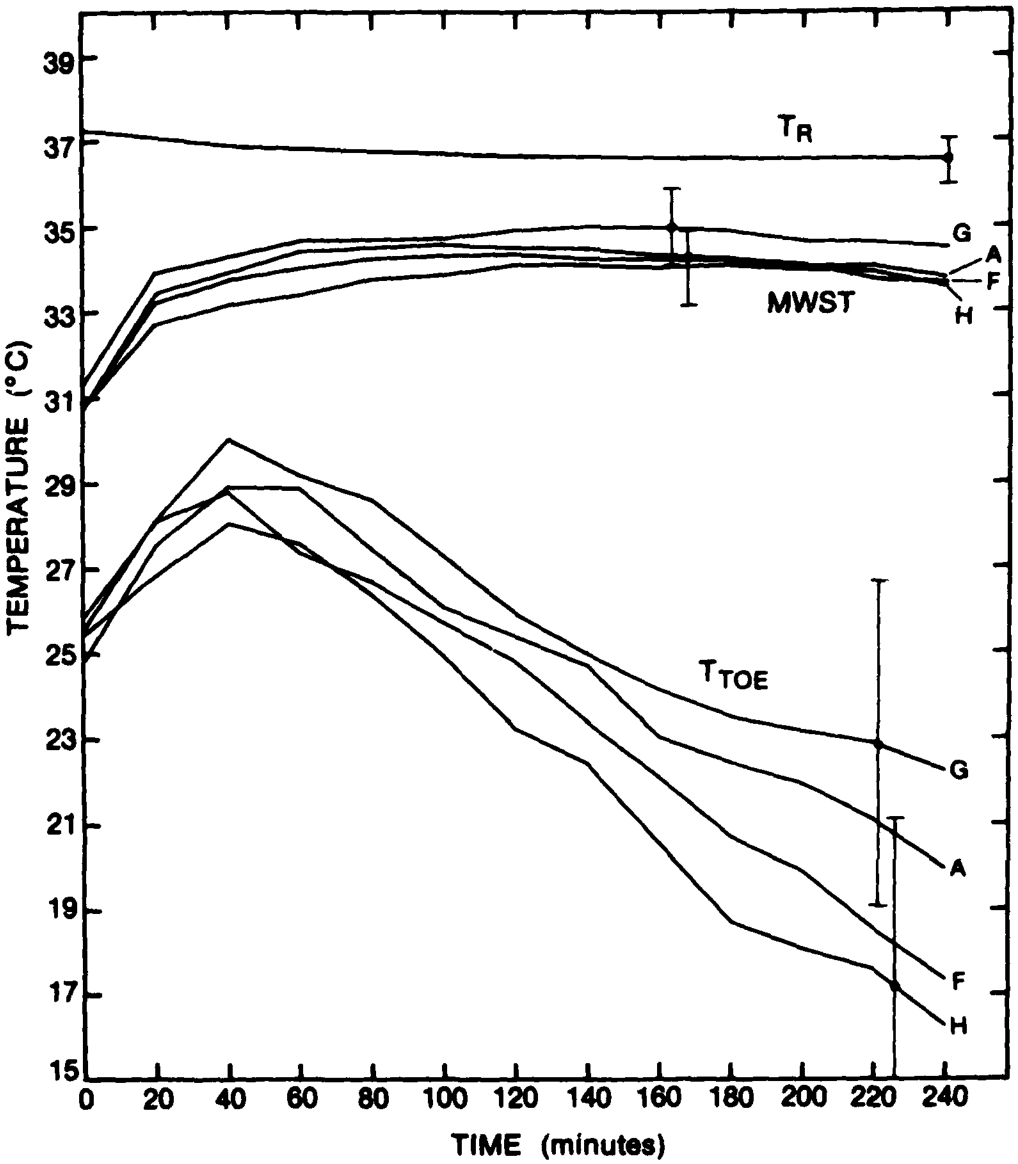


Fig. 18: Mean Changes in T_R, MWST and T_{TOE}.

Representative error bars are indicated by vertical lines. During the test period the mean rectal temperatures of subjects using each of the types of sleeping bag gradually decreased by approximately 0.2°C, but mean values of each type of bag were virtually indistinguishable. In general, mean weighted skin temperature increased about 3°C during the first 20 minutes of the test and then remained constant for the duration of the period. Mean values of MWST during the duration of the test for each of the types of sleeping bag were equal within the limits of experimental error. Mean toe temperature increased by about 4°C during the first 40 minutes of the test and then gradually decreased by 6-10°C during the next 200 minutes. Although analysis of variance indicates that these mean results are significantly different, the practical significance of the difference is not well defined due to the large variation between individual measurements.

Although objective temperature measurements indicated that there was little difference in the thermal protection afforded by each type of sleeping bag, the test subjects were unanimous in ranking the sleeping bags in the following order (most comfortable to least comfortable):

First phase:	C (X79-013)	- Laminate of Polarguard #220 and #115
	B (X79-012)	- Hollofil #350
	A	- Current CF bag
	D (X79-018)	- Thinsulate CS-300B
	E (X79-021)	- Polydown 50/50 polyester/down
Second phase:	G (X79-015)	- Laminate of 2 layers Polarguard #220
	A	- Current CF bag
	F (X79-014)	- Laminate of 2 layers Polarguard #115
	H (X79-017)	- Polarguard #255

Because the evaluation was conducted in two phases at different times of the year (May-June and November-December), a clear choice between bag C and G (laminate of two layers of Polarguard #220 and laminate of Polarguard #220 and #115, respectively) cannot be made. However, all subjects felt that sleeping bags D, E and H (Thinsulate CS-300B, Polydown 50/50 and Polarguard #255, respectively) offered inferior thermal protection and would not have chosen any of these for use at -23°C. It should be noted that the sleeping bag manufactured using Polarguard #255 contained the least amount of insulating material (total weight 1840 g) of all of the bags tested.

It is interesting to note that, in general, if the sleeping bags are ranked in order of decreasing toe temperature, the ranking corresponds to the subjective ranking of the sleeping bags in order of comfort. Neither the test subjects nor the authors were aware of this result during the experiments.

CONCLUSIONS

Under the conditions of the physiological evaluations described, the results indicate the following:

1. At an ambient temperature of -23°C, no significant differences in thermal protection afforded by each type of sleeping bag were found when T_R, MWST or T_{TB} were compared.

2. Mathematically significant differences in toe temperatures, hours of sleep and amount of moisture absorbed were observed but these differences are not considered to be physically important.

3. Subjectively, the test subjects were unanimous in ranking the sleeping bags in order of preference. Bags manufactured using Polarguard #220 and #115 and Hollofil #350 were felt to be superior to the current CF bag. The Thinsulate CS-300B, Polydown and Polarguard #255 sleeping bags were considered to offer inferior thermal protection.

OVERALL CONCLUSIONS

Polarguard was found to be the best substitute for down-and-feathers for use in sleeping bags. Hollofil was rejected because of its poor washing characteristics, the Thinsulates because of their low thermal resistance per unit mass and the negative subjective response to it by the test subjects.

REFERENCES

1. B. Farnworth, R.M. Crow and M.M. Dewar, Measurements and Calculations of the Thermal Resistance of Three Synthetic-Fibre Battings. DREO Report No. 818, 1979.

2. R. Osczevski and B. Farnworth, Thermal Properties of Battings and Their Potential in Improved Sleeping Bags. CDA 16, Thirteen Commonwealth Defence Conference on Operational Clothing and Combat Equipment, Malaysia 1981.

3. Development Test II (Service Phase) of Cold Weather Sleeping Gear Under Arctic Winter Conditions. Final Report. US Army Arctic Test Center, APO Seattle, 98733, 31 May 1973.

4. R.W. Nolan and S.W. Cattroll, A Physiological Assessment of Arctic Sleeping Bags Under Cold Weather Conditions. DREO Technical Note No. 75-22, November 1975.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the cooperation of members of the CF/DREO Test Team who volunteered to participate in this evaluation.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1 ORIGINATING ACTIVITY Defence Research Establishment Ottawa Department of National Defence Ottawa, Ontario, Canada K1A 0Z4	2a. DOCUMENT SECURITY CLASSIFICATION UNCLASSIFIED 2b GROUP
3 DOCUMENT TITLE COMPARISON OF DOWN-AND-FEATHERS AND SYNTHETIC INSULANTS FOR USE IN SLEEPING BAGS	
4 DESCRIPTIVE NOTES (Type of report and inclusive dates) REPORT	
5 AUTHOR(S) (Last name, first name, middle initial) CROW, Rita M., NOLAN, Richard W., CATTROLL, Stanley W. and DEWAR, Malcolm M.	
6 DOCUMENT DATE JULY 1982	7a TOTAL NO OF PAGES 39 7b NO OF REFS 4
8a. PROJECT OR GRANT NO	9a ORIGINATOR'S DOCUMENT NUMBER(S) DREO REPORT No. 866
8b CONTRACT NO	9b OTHER DOCUMENT NO (S) (Any other numbers that may be assigned this document)
10 DISTRIBUTION STATEMENT UNLIMITED DISTRIBUTION	
11 SUPPLEMENTARY NOTES	12. SPONSORING ACTIVITY DCGEM

13 ABSTRACT

A study was carried out to evaluate and compare physically and physiologically three types of synthetic insulating materials and the in-service Canadian Forces down-and-feathers sleeping bag with the ultimate aim of replacing the latter. The insulating materials evaluated were Thinsulate, Polarguard and Hollofil. Polarguard was found to be the optimum substitute for the down-and-feathers.

UNCLASSIFIED

DSIS
77-065

Li

UNCLASSIFIED

Security Classification

KEY WORDS

THERMAL RESISTANCE

THICKNESS

MASS

WASHING

BEDDING EQUIPMENT

COLD WEATHER TESTS

COMPARATIVE PHYSIOLOGY

INSTRUCTIONS

1. ORIGINATING ACTIVITY Enter the name and address of the organization issuing the document.

2a DOCUMENT SECURITY CLASSIFICATION Enter the overall security classification of the document including special warning terms whenever applicable.

2b GROUP Enter security reclassification group number. The three groups are defined in Appendix 'M' of the DRB Security Regulations.

3. DOCUMENT TITLE Enter the complete document title in all capital letters. Titles in all cases should be unclassified. If a sufficiently descriptive title cannot be selected without classification, show title classification with the usual one-capital-letter abbreviation in parentheses immediately following the title.

4 DESCRIPTIVE NOTES Enter the category of document, e.g. technical report, technical note or technical letter. If appropriate, enter the type of document, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.

5 AUTHOR(S): Enter the name(s) of author(s) as shown on or in the document. Enter last name, first name, middle initial. If military, show rank. The name of the principal author is an absolute minimum requirement.

6 DOCUMENT DATE Enter the date (month, year) of Establishment approval for publication of the document.

7a TOTAL NUMBER OF PAGES The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b NUMBER OF REFERENCES Enter the total number of references cited in the document.

8a PROJECT OR GRANT NUMBER If appropriate, enter the applicable research and development project or grant number under which the document was written.

8b CONTRACT NUMBER If appropriate, enter the applicable number under which the document was written.

9a ORIGINATOR'S DOCUMENT NUMBER(S) Enter the official document number by which the document will be identified and controlled by the originating activity. This number must be unique to this document.

9b. OTHER DOCUMENT NUMBER(S) If the document has been assigned any other document numbers (either by the originator or by the sponsor), also enter this number(s).

10. DISTRIBUTION STATEMENT Enter any limitations on further dissemination of the document, other than those imposed by security classification, using standard statements such as

(1) "Qualified requesters may obtain copies of this document from their defence documentation center."

(2) "Announcement and dissemination of this document is not authorized without prior approval from originating activity."

11. SUPPLEMENTARY NOTES Use for additional explanatory notes.

12. SPONSORING ACTIVITY Enter the name of the departmental project office or laboratory sponsoring the research and development. Include address.

13. ABSTRACT Enter an abstract giving a brief and factual summary of the document, even though it may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall end with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (TS), (S), (C), (R), or (U).

The length of the abstract should be limited to 20 single-spaced standard typewritten lines, 7½ inches long.

14. KEY WORDS. Key words are technically meaningful terms or short phrases that characterize a document and could be helpful in cataloging the document. Key words should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context.